

VIBRATION MEASURING METHOD AND VIBRATION MEASURING SYSTEM

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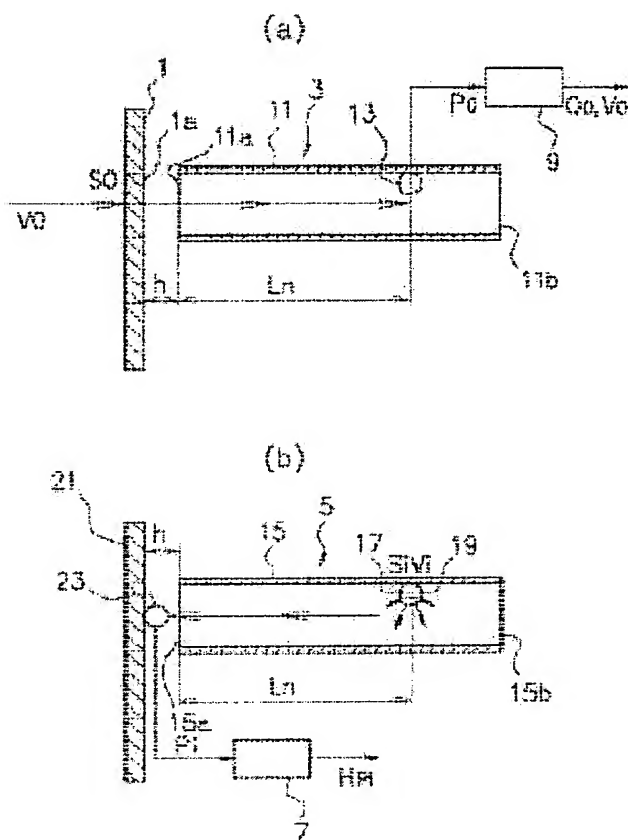
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Abstract of JP 2002195876 (A)

PROBLEM TO BE SOLVED: To provide a non-contact vibration measuring method capable of removing the effect of sound sources near a measured surface by a simple installation and capable of performing measurement in a short time.

SOLUTION: A first sound tube 11 is disposed so that its opening 11a is apart from the measured surface 1a by a distance h . The sound pressure P_0 of a sound emitted from the measured surface 1a is measured in the sound tube 11 at a position apart from the opening 11a by a prescribed distance L_n . A vibration plate 17 having a prescribed area S_i and vibrating at a vibration speed V_i is disposed in a second sound tube 15 capable of exhibiting a propagation characteristic nearly equal to that of the sound tube 11 at a position apart from its opening 15a by the prescribed distance L_n .; The sound pressure P_i of a sound emitted from the vibration plate 17 is measured outside the sound tube 15 at a position confronting the opening 15a and apart from the opening 15a by the prescribed distance h . A propagation characteristic H_{Pi} is calculated from the area S_i , vibration speed V_i , and sound pressure P_i , according to $H_{Pi} = S_i \times V_i / P_i$. The volume velocity Q_0 of the measured surface is calculated from the propagation characteristic H_{Pi} and the sound pressure P_0 , according to $V_0 = P_0 \times H_{Pi}$.



Machine translation JP2002195876**(Bibliographic data + Summary + Claim)**

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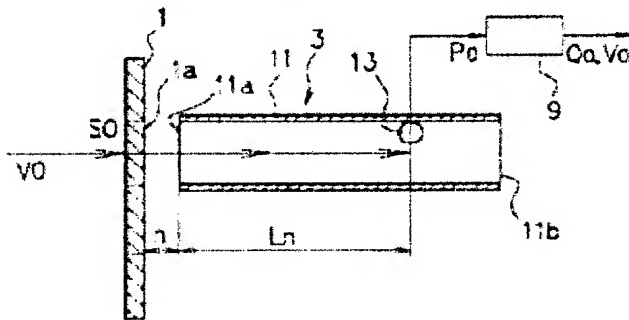
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Abstract:

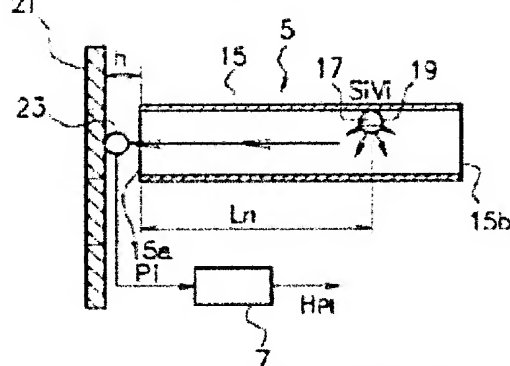
PROBLEM TO BE SOLVED: To provide a non-contact vibration measuring method capable of removing the effect of sound sources near a measured surface by a simple installation and capable of performing measurement in a short time.SOLUTION: A first sound tube 11 is disposed so that its opening 11a is apart from the measured surface 1a by a distance h. The sound pressure P0 of a sound emitted from the measured surface 1a is measured in the sound tube 11 at a position apart from the opening 11a by a prescribed distance Ln. A vibration plate 17 having a prescribed area Si and vibrating at a vibration speed Vi is disposed in a second sound tube 15 capable of exhibiting a propagation characteristic nearly equal to that of the sound tube 11 at a position apart from its opening 15a by the prescribed distance Ln. The sound pressure Pi of a sound emitted from the vibration plate 17 is measured outside the sound tube 15 at a position confronting the opening 15a and apart from the opening 15a by the

prescribed distance h . A propagation characteristic H_{Pi} is calculated from the area S_i , vibration speed V_i , and sound pressure P_i , according to $H_{Pi} = S_i \times V_i / P_i$. The volume velocity Q_0 of the measured surface is calculated from the propagation characteristic H_{Pi} and the sound pressure P_0 , according to $V_0 = P_0 \times H_{Pi}$.

(a)



(b)



JPO Machine translation abstract:

(57) **Abstract**(Modified)

Technical problem Offer of the oscillating instrumentation method by non-contact measurable / that the influence of the sound source near the measured plane can be eliminated with easy equipment / with a short time .

Means for Solution The 1st sounding tube 11 is arranged so that the opening 11a may estrange only the distance h from the measured plane 1a, The sound pressure P_0 of a sound emitted from the measured plane 1a in a position which estranged only the prescribed distance L_n from the opening 11a within the 1st sounding tube 11 is measured, The diaphragm 17 which has prescribed area S_i and vibrates by the velocity of vibration V_i is arranged so that only the prescribed distance L_n may be estranged from the opening 15a in the 2nd sounding tube 15 that can demonstrate a propagation characteristic almost equal to the 1st sounding tube 11, The sound pressure P_i of a sound emitted from the diaphragm 17 in a position which counters with the opening 15a out of the 2nd sounding tube 15, and estranges only the prescribed distance h from the opening 15a is measured, According to $H_{pi} = S_i \times V_i / P_i$, the propagation characteristic H_{pi} is computed from area S_i , the velocity of vibration V_i , and the sound pressure P_i , and the volume velocity Q_0 of a measured plane is computed according to $V_0 = P_0 \times H_{pi}$ from this propagation characteristic H_{pi} and the sound pressure P_0 .

Claim(s)

Claim 1 The 1st sounding tube that has an opening at the end is arranged so that this opening may estrange only the prescribed distance h from a measured plane, The sound pressure P_0 of a sound emitted from said measured plane in a position which estranged only the prescribed distance L_n from said opening within said 1st sounding tube is measured, It arranges so that only said prescribed distance L_n may be estranged from said opening in the 2nd sounding tube that has an opening for a diaphragm which has prescribed area S_i and vibrates by the velocity of vibration V_i at the end, and can demonstrate a propagation characteristic almost equal to

said 1st sounding tube, The sound pressure P_i of a sound emitted from said diaphragm in a position which counters with said opening out of said 2nd sounding tube, and estranges only said prescribed distance h from this opening is measured, An oscillating instrumentation method computing the propagation characteristic H_{pi} according to following formula $H_{pi} = S_i \times V_i / P_i$ from said area S_i , the velocity of vibration V_i , and the sound pressure P_i , and computing the volume velocity Q_0 of a measured plane according to following formula $Q_0 = P_0 \times H_{pi}$ from said propagation characteristic H_{pi} and the sound pressure P_0 .

Claim 2 An oscillating instrumentation method which is the oscillating instrumentation method according to claim 1, and is characterized by blockading the other end of said 1st sounding tube.

Claim 3 An oscillating instrumentation method which is the oscillating instrumentation method according to claim 1 or 2, and is characterized by arranging a sound-absorbing material at least in a part on each inner skin of said 1st and 2nd sounding tubes.

Claim 4 According to following formula $H_{pi} = S_i \times V_i / P_i$, the propagation characteristic H_{pi} is computed from the 2nd sound pressure measuring device characterized by comprising the following, said area S_i and the velocity of vibration V_i , and the sound pressure P_i , this propagation characteristic H_{pi} and the sound pressure P_0 . from -- following following formula $V_0 = P_0 \times H_{pi}$ -- the volume velocity Q_0 of a measured plane An oscillating instrumentation system provided with operation part to compute

The 1st sounding tube arranged so that it may have an opening at the end and this opening may estrange only the prescribed distance h from a measured plane.

The 1st sound pressure test section that measures the sound pressure P_0 of a sound which is arranged in said 1st sounding tube and emitted from said measured plane so that only the prescribed distance L_n may be estranged from said opening.

The 1st sound pressure measuring device it has.

The 2nd sounding tube that has an opening at the end and can demonstrate a propagation characteristic almost equal to said 1st sounding tube, A diaphragm which is arranged in said 2nd sounding tube, has prescribed area S_i , and vibrates by the velocity of vibration V_i so that only said prescribed distance L_n may be estranged from said opening, The 2nd sound pressure test section that measures the sound pressure P_i of a sound which is arranged out of said 2nd sounding tube, and is emitted from said diaphragm so that it may counter with this opening in a position which estranged only said prescribed distance h from said opening.

Claim 5 An oscillating instrumentation system which is the oscillating instrumentation system according to claim 4, and is characterized by blockading the other end of said 1st sounding tube.

Claim 6 An oscillating instrumentation system which is the oscillating instrumentation system according to claim 4 or 5, and is characterized by arranging a sound-absorbing material at least in a part on each inner skin of said 1st and 2nd sounding tubes.

Detailed Description of the Invention

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Field of the Invention This invention relates to the method and device which measure surface vibration of a structure.

0002

Description of the Prior Art In order to measure vibration of a structure generally, the accelerometer is used widely. However, when vibration of a low-mass portion was measured like measurement of surface vibration of the thin gauge structure which noise tends to generate, or measurement of the plane of vibration of a loudspeaker, even if it used the small accelerometer, there was inconvenience that the mass will affect a measurement value.

0003 On the other hand, according to the technique of asking for the velocity of vibration by non-contact, it is possible to perform oscillating measurement of a low-mass portion correctly. As such a technique, the method of using a laser Doppler velocimeter (LDV), the sound intensity method, the acoustical holography method, etc. are known.

0004

Problem(s) to be Solved by the Invention Although the sound intensity method is used widely and is well known also as particle-velocity mensuration, when a strong sound source exists near the portion under test, there is a problem that a possibility that a measurement error will increase that it is easy to receive the influence is high. By the method and acoustical

holography method for using LDV, there is inconvenience that equipment is large-scale and that it is expensive, in the method of using especially LDV, it is easy to receive change of the reflectance of a portion under test, and the influence of shape, and there is also a problem that measuring time including adjusting time takes great time.

0005This invention was made in view of the above-mentioned actual condition, and is ****. The purpose does not need equipment, but the influence of the sound source near the measured plane can be eliminated, and it is offer of the oscillating instrumentation method of the structure by non-contact **measurable with a short time** , and a ***** system.

0006

Means for Solving the ProblemAn oscillating instrumentation method concerning this invention that the above-mentioned purpose should be attained, The 1st sounding tube that has an opening at the end is arranged so that this opening may estrange only the prescribed distance h from a measured plane, The sound pressure P0 of a sound emitted from said measured plane in a position which estranged only the prescribed distance Ln from said opening within said 1st sounding tube is measured, It arranges so that only said prescribed distance Ln may be estranged from said opening in the 2nd sounding tube that has an opening for a diaphragm which has prescribed area Si and vibrates by the velocity of vibration Vi at the end, and can demonstrate a propagation characteristic almost equal to said 1st sounding tube, The sound pressure Pi of a sound emitted from said diaphragm in a position which counters with said opening out of said 2nd sounding tube, and estranges only said prescribed distance h from this opening is measured, According to following formula $H_{pi} = S_i \times V_i / P_i$, the propagation characteristic Hpi is computed from said area Si, the velocity of vibration Vi, and the sound pressure Pi, and the volume velocity Q0 of a measured plane is computed according to following formula $V_0 = P_0 \times H_{pi}$ from this propagation characteristic Hpi and the sound pressure P0.

0007An oscillating instrumentation system concerning this invention is provided with the following.

The 1st sound pressure measuring device.

The 2nd sound pressure measuring device.

Operation part.

0008The 1st sounding tube arranged so that said 1st sound pressure measuring device may have an opening at the end and this opening may estrange only the prescribed distance h from a measured plane, It has the 1st sound pressure test section that measures the sound pressure P0 of a sound which is arranged in said 1st sounding tube and emitted from said measured plane so that only the prescribed distance Ln may be estranged from said opening. The 2nd sounding tube that said 2nd sound pressure measuring device has an opening at the end, and can demonstrate a propagation characteristic almost equal to said 1st sounding tube, A diaphragm which is arranged in said 2nd sounding tube, has prescribed area Si, and vibrates by the velocity of vibration Vi so that only said prescribed distance Ln may be estranged from said opening, It has the 2nd sound pressure test section that measures the sound pressure Pi of a sound which is arranged out of said 2nd sounding tube, and is emitted from said diaphragm so that it may counter with this opening in a position which estranged only said prescribed distance h from said opening. Said operation part computes the propagation characteristic Hpi according to following formula $H_{pi} = S_i \times V_i / P_i$ from said area Si, the velocity of vibration Vi, and the sound pressure Pi, and computes the volume velocity Q0 of a measured plane according to following formula $V_0 = P_0 \times H_{pi}$ from this propagation characteristic Hpi and the sound pressure P0.

0009According to the above-mentioned instrumentation method and the instrumentation system, the volume velocity Q0 of a measured plane is called for by a noncontact state from a measured plane. Since a large device is not included on structure, large-scale equipment is not needed, Since it is reflected in an outer wall of the 1st sounding tube, the radiation sound from other than a measured plane can eliminate influence of a sound source near the measured plane, and further, that it is hard to receive change of reflectance of a measured plane, and influence of shape, since adjusting time is unnecessary, it can measure it in a short time.

0010In the above-mentioned instrumentation method and an instrumentation system, the other end of said 1st sounding tube may be blockaded. Thereby, influence of a radiation sound from other than a measured plane can be eliminated still more certainly, and the accuracy of measurement improves. The other end of the 2nd sounding tube may be blockaded similarly.

0011In the above-mentioned instrumentation method and an instrumentation system, a

sound-absorbing material may be arranged at least to a part which it is on each inner skin of said 1st and 2nd sounding tubes. Thereby, generating of resonance is controlled in the 1st and 2nd sounding tubes, and the accuracy of measurement improves.

0012In an aforesaid measuring method and a measurement system, it may be one sounding tube with which said 1st sounding tube and said 2nd sounding tube are common. Thereby, since the 1st sounding tube and 2nd sounding tube can demonstrate a certainly equal propagation characteristic, the accuracy of measurement improves. Since it is not necessary to form two or more sounding tubes, simplification of a system is attained.

0013As for a cross-section area of said 1st and 2nd sounding tubes, in an aforesaid measuring method and a measurement system, it is preferred to be set up smaller than area which serves as a plane wave to object upper limited frequency. Thereby, since a measured plane and a radiation sound from a diaphragm are spread, respectively, without decreasing inside of the 1st and 2nd sounding tubes, their accuracy of measurement improves.

0014The sound pressure P_i of a sound emitted from said diaphragm on the surface of a rigid high member by position which counters with said opening out of said 2nd sounding tube, and estranges only said prescribed distance h from this opening in an aforesaid measuring method and a measurement system may be measured, Said 1st sounding tube may be arranged along a normal line direction of said measured plane.

0015The velocity of vibration V_0 of a measured plane may be computed according to following formula $V_0 = Q_0 / S_0$ from the volume velocity Q_0 and the area S_0 of a measured plane.

0016

Embodiment of the Invention Hereafter, one embodiment of this invention is described based on a drawing.

0017They are a mimetic diagram showing the state where drawing 1 (a) does not have a mimetic diagram of the 1st sound pressure measuring device of this embodiment, drawing 1 (b) does not have a mimetic diagram of the 2nd sound pressure measuring device of this embodiment, and drawing 2 (a) does not have the 1st sounding tube, and a mimetic diagram showing the state where drawing 2 (b) has the 1st sounding tube.

0018First, the basic constitution of the instrumentation system concerning this embodiment is explained.

0019As shown in drawing 1 (a) and drawing 1 (b), the instrumentation system concerning this embodiment is provided with the following.

The 1st sound pressure measuring device 3.

The 2nd sound pressure measuring device 5.

Operation part 7 and 9.

0020The arbitrary parting planes (measured plane) 1a of the vibrating wall 1 which is a measuring object had the prescribed area S_0 , and the 1st sound pressure measuring device 3 is provided with the 1st sounding tube 11 and 1st microphone (1st sound pressure test section) 13. The 1st sounding tube 11 is a tube-like object made of metal or resin in which the same sectional shape follows linear shape along with the medial axis, and the openings 11a and 11b which present said sectional shape are formed in the both ends. The 1st sounding tube 11 has been arranged along the normal line direction of the parting plane 1a, and the opening 11a of an end has estranged only the prescribed distance h from the parting plane 1a. The microphone 13 is arranged in the 1st sounding tube 11 so that only the prescribed distance L_n may be estranged along with a medial axis from the opening 1a, it measures the sound pressure P_0 of the sound emitted from the parting plane 1a, and outputs it to the operation part 9. The operation part 9 computes and outputs the volume velocity Q_0 and/or the velocity of vibration V_0 by the method of mentioning later.

0021The 2nd sound pressure measuring device 5 is provided with the following.

The 2nd sounding tube 15.

The loudspeaker 19 which has the diaphragm 17.

The rigid high support plate 21.

The 2nd microphone (2nd sound pressure test section) 23.

0022The 2nd sounding tube 15 is a tube-like object made of metal or resin in which the same sectional shape follows linear shape along with the medial axis like the 1st sounding tube 11, and the openings 15a and 15b which present said sectional shape are formed in the both ends. The 2nd sounding tube 15 has shape almost equal to the 1st sounding tube 11, a size, and construction material so that a propagation characteristic almost equal to the 1st sounding tube

11 can be demonstrated. As long as the state where insulation is very high is acquired necessarily identically as for these elements, both construction material may be different.

0023The diaphragm 17 is arranged in the 2nd sounding tube 15 so that only the prescribed distance L_n may be estranged along with a medial axis from the opening 15a of an end. The diaphragm 17 has prescribed area S_i and vibrates by the velocity of vibration V_i . The support plate 21 is arranged almost vertically to the medial axis of the 2nd sounding tube 15 at the position which counters with the opening 15a out of the 2nd sounding tube 15, and estranges only the prescribed distance h from the opening 15a. It is fixed on the outside surface of the support plate 21 in the position which estranged only the prescribed distance h from the opening 15a, and the microphone 23 measures the sound pressure P_i of the sound emitted from the diaphragm 17, and outputs it to the operation part 7. The operation part 7 computes and outputs the propagation characteristic H_{pi} by the method of mentioning later.

0024Thus, the 1st sound pressure measuring device 3 and the 2nd sound pressure measuring device 5 are constituted equivalent about the propagation characteristic of a sound.

0025Next, the instrumentation method concerning this embodiment is explained.

0026The 1st sound pressure measuring device 3 and the 2nd sound pressure measuring device 5, Since it is constituted equivalent about the propagation characteristic of a sound, the volume velocity Q_0 of a reciprocity theorem to the parting plane 1a, The relation of a following formula (1) is materialized between the sound pressure P_0 detected with the microphone 13, the volume velocity Q_i of the diaphragm 17, the sound pressure P_i detected with the microphone 23, and the propagation characteristic H_{pi} .

0027 $Q_0 / P_0 = Q_i / P_i = H_{pi} \text{ -- (1)}$

Here, as for the volume velocity Q_0 , the area S_0 and the velocity of vibration V_0 of the parting plane 1a ask for the volume velocity Q_i by area S_i and the velocity of vibration V_i of the diaphragm 17 according to a following formula (2) and (3), respectively.

0028 $Q_0 = S_0 \times V_0 \text{ -- (2)}$

$Q_i = S_i \times V_i \text{ -- (3)}$

Therefore, the following formula (4), (5), and (6) is called for from a formula (1), (2), and (3).

0029 $H_{pi} = S_i \times V_i / P_i \text{ -- (4)}$

$Q_0 = P_0 \times H_{pi} \text{ -- (5)}$

$V_0 = P_0 \times H_{pi} / S_0 \text{ -- (6)}$

When measuring the volume velocity Q_0 and/or the velocity of vibration V_0 of a sound which are emitted from the parting plane 1a, first, the 2nd sound pressure measuring device 5 is used, the sound pressure P_i of the sound emitted from the loudspeaker 19 (diaphragm 17) is detected with the microphone 23, and it is inputted into the operation part 7. Area S_i and the velocity of vibration V_i of the diaphragm 17 are beforehand inputted into the operation part 7, and are memorized, and the propagation characteristic H_{pi} is computed according to a formula (4) from these P_i , S_i , and V_i .

0030Next, the 1st sound pressure measuring device 3 is used, the sound pressure P_0 of the sound emitted from the parting plane 1a is detected with the microphone 13, and it is inputted into the operation part 9. The propagation characteristic H_{pi} computed by the operation part 7 and the area S_0 of the parting plane 1a are beforehand inputted into the operation part 9, and are memorized, and the volume velocity Q_0 and/or the velocity of vibration V_0 of the parting plane 1a are computed according to these P_0 , H_{pi} , and S_0 to a formula (5) and/or (6). When only the volume velocity Q_0 is computed, the area S_0 of the parting plane 1a does not need to be inputted into the operation part 9.

0031According to such an instrumentation method and an instrumentation system, it can ask for the volume velocity Q_0 and/or the velocity of vibration V_0 of the parting plane 1a by a noncontact state from the parting plane 1a.

0032Since a large device is not included on structure, large-scale equipment is not needed.

0033The radiation sound from other than parting plane 1a is reflected in the outer wall of the 1st sounding tube 11. For example, if sound pressure P_m near the parting plane 1a is measured with the microphone 25 in the state where the 1st sounding tube 11 is not formed as shown in drawing 2 (a), sound pressure P_m detected will be influenced by leak lump of the oscillating radiation sound P_j from an adjoining parting plane. For this reason, detection of the radiation sound only from the parting plane 1a which is a measuring object is difficult. On the other hand, as shown in drawing 2 (b), where the 1st sounding tube 11 is formed. It is reflected in the outer wall of the 1st sounding tube 11, and the radiation sound from other than parting plane 1a is spread inside the sounding tube 11 by only the plane wave according to the velocity of vibration V_0 of the parting plane 1a, and can measure the sound pressure P_0 with the microphone 11.

That is, the influence of the sound source near the parting plane 1a can be eliminated.

0034That it is hard to receive change of the reflectance of a measured plane (parting plane 1a), and the influence of shape, since adjusting time is unnecessary, it can measure extremely in a short time.

0035The sectional shape in particular of the 1st sounding tube 11 and the 2nd sounding tube 15 is not limited, and shape with various circular, rectangles, etc. may be applied.

0036The 1st sounding tube 11 and 2nd sounding tube 15 may be one common sounding tube. Thereby, since the 1st sounding tube and 2nd sounding tube can demonstrate a certainly equal propagation characteristic, the accuracy of measurement improves. Since it is not necessary to form two or more sounding tubes, simplification of a system is attained.

0037The cross-section area of the 1st and 2nd sounding tubes 11 and 15, It is preferred that the sectional shape of being set up smaller than the area which serves as a plane wave to object upper limited frequency, for example, the inner skin of the 1st and 2nd sounding tubes 11 and 15, is set as the size and shape which contain thoroughly the shape almost equal to a periphery edge or this shape of the parting plane 1a inside. Thereby, since the parting plane 11a and the radiation sound from the diaphragm 17 are spread, respectively, without decreasing the inside of the 1st and 2nd sounding tubes 11 and 15, their accuracy of measurement improves.

0038By sticking and arranging the sound-absorbing material 27 on each inner skin of the 1st and 2nd sounding tubes 11 and 15, generating of resonance is controlled in the 1st and 2nd sounding tubes 11 and 15, and the accuracy of measurement improves. It is demonstrated even if the depressor effect of resonance is not established throughout each inner skin of the 1st and 2nd sounding tubes 11 and 15, For example, if it provides in the field of a semicircle as shown in drawing 3 (a) when the sounding tubes 11 and 15 are cylindrical, the effect will fully be acquired, and if it provides throughout one inner surface among four inner surfaces as shown in drawing 3 (b) when it is rectangular cylinder form, the effect will fully be acquired. Since the composition of the 2nd sounding tube 15 is almost the same as that of the 1st sounding tube 11, the graphic display is omitted.

0039By blockading the other end 11b of the 1st sounding tube 11, the influence of the radiation sound from other than parting plane 1a can be eliminated still more certainly, and the accuracy of measurement improves. In this case, although it is also possible to blockade the other end 11b by the sounding tube 11, the lid formed in one, etc., it is most preferred for it to be more desirable to blockade with the sound-absorbing material 29, as shown in drawing 4, and to provide with the sound-absorbing material 27 on inner skin further. Also in the 2nd sounding tube 15, influence can be eliminated from the exterior by blockading similarly the other end 15b of the 2nd sounding tube 15.

0040Next, the conducted experiment using the instrumentation system concerning this embodiment is explained.

0041As shown in drawing 5 (a), in the 1st sound pressure measuring device 3 used in the experiment, the vibrating wall 1 which is a noise source is formed in the shape of a rectangular plate object of a 2-mm-thick griddle, and is being fixed to the buck 31. The buck 31 is formed in the shape of **which has an open face on the whole surface** a box, and it is arranged so that an open face may be horizontally suitable. The vibrating wall 1 is concluded by the edge part of the open face with two or more bolts so that the open face of the buck 31 may be blockaded. The loudspeaker 33 is being fixed on the field which carries out for relativity to the vibrating wall 1 in the buck 31. The buck 31 is formed of the griddle which has 10 sufficient mm in thickness so that the sound emitted from the loudspeaker 33 may be emitted by sound excitation only from the vibrating wall 1. 20 division (four rows by five rows) of the outside surface of the vibrating wall 1 which is a sound source is carried out, and the one parting plane 1a is set as the approximately square of 80 mm x 80 mm.

0042The 1st sounding tube 11 is formed in the shape of **which has sectional shape and a size almost equal to the parting plane 1a** a rectangle barrel, and is attached to the traverse device besides a graphic display. The traverse device is supporting the 1st sounding tube 11 to the parting plane 1a, enabling free movement in a parallel direction and a vertical direction, where the normal line direction of the outside surface (parting plane 1a) of the vibrating wall 1 is met. Length L of the sounding tube 11 is set as 40 mm so that the sound pressure in the sounding tube 11 may not be influenced by surroundings lump. The distance Ln from the opening 11a of the sounding tube 11 to the microphone 13 is set as 30 mm so that the radiation sound from the vibrating wall 1 (parting plane 1a) may serve as a plane wave certainly.

0043 Measurement of the radiation sound from the vibrating wall 1 moved the 1st sounding tube 11 to each parting plane 1a with a traverse device, and was performed by measuring the sound pressure P_i in the sounding tube 11 with the microphone 13 on the basis of the input voltage E from the power amplification 39 to the loudspeaker 33. Under the present circumstances, the position of the sounding tube 11 to each parting plane 1a was adjusted so that the sounding tube 11 might be arranged along the normal line direction of each parting plane 1a and the opening 11a of the end of the sounding tube 11 might estrange only the prescribed distance h from each parting plane 1a. About this distance h , it measured about three conditions (1 mm, 5 mm, and 15 mm).

0044 Simultaneously, for comparison with the result obtained by this experiment, the reflection type besides a graphic display was stuck on each parting plane 1a, and the velocity of vibration was measured, adjusting an optic axis to each parting plane 1a of every using the noncontact laser vibration meter (LDV) 37. LDV37 was used in order to eliminate the influence of the mass by an accelerometer.

0045 As shown in drawing 5 (b), in the 2nd sound pressure measuring device 5 used for the experiment, the support plate 21 is formed with iron material with a thickness of 30 mm which has sufficient rigidity. The microphone 23 is embedded at the support plate 21 so that it may be located on the outside surface of the support plate 21 in which the sound-collecting part carries out for relativity to the opening 15a of the end of the 2nd sounding tube 15. The 2nd sounding tube 15 has the 1st size and shape almost equal to the sounding tube 11, and it is arranged so that the normal line direction of opposite *Perilla frutescens* (L.) Britton var. *crispa* (Thunb.) Decne. may be met at the support plate 21. The area of the diaphragm besides the graphic display of the loudspeaker 19 in the 2nd sounding tube 15 is beforehand set as the prescribed area S_0 .

0046 Measurement of the radiation sound from the loudspeaker 19 was performed by measuring the sound pressure P_0 of the radiation sound from the loudspeaker 19 with the microphone 23 on the basis of the input voltage e from the power amplification 43 to the loudspeaker 19. About the distance h along said normal line direction of the microphone 23 and the opening 15a of the sounding tube 15, it measured about three conditions (1 mm, 5 mm, and 15 mm).

0047 Simultaneously, it measured by LDV besides a graphic display of the velocity of vibration V_0 of the diaphragm besides the graphic display in the loudspeaker 19. Having used LDV has the dramatically small mass of a diaphragm, and it is easy to generate partial vibration and rolling in response to the influence by the weight in a contact type.

0048 The sound pressure P_i of the radiation sound from the loudspeaker 19 measured with the microphone 23 is inputted into the high speed operation device (FFT) 41 as the operation part 7. The velocity of vibration V_i measured by the area S_i and LDV of the diaphragm 17 is beforehand inputted into FFT41, and is memorized, and the propagation characteristic H_{pi} is computed and outputted to it at each distance h of every according to said formula (4) from P_i , S_i , and V_i .

0049 The sound pressure P_0 of the radiation sound from the parting plane 1a measured with the microphone 13 of the 1st sound pressure measuring device 3 is inputted into the high speed operation device (FFT) 35 as the operation part 9. The propagation characteristic H_{pi} computed by FFT41 and the area S_0 of the parting plane 1a are beforehand inputted into FFT35, and are memorized. The volume velocity Q_0 is computed by every parting plane 1a according to these P_0 , H_{pi} , and S_0 to said formula (5) and/or (6), and the aggregate value σ_{Q0} is outputted eventually. The velocity of vibration measured by LDV37 is also inputted into FFT35. In FFT35, by multiplying the velocity of vibration measured by LDV37 by the area S_0 of the parting plane 1a, the theoretical value of the volume velocity in this experiment is computed by every parting plane 1a, and the aggregate value σ_{Qt} is outputted eventually.

0050 Next, the result of this experiment is explained based on drawing 6 - drawing 9.

0051 The propagation characteristic H_p of each distance h of every **which was outputted from FFT41** is expressed to drawing 6. It was checked that a level also increases, when the frequency characteristic showed the identical trend and its distance h increased, although there was a level difference by the distance h as shown in drawing 6.

0052 The aggregate value (experimental value) σ_{Q0} of the volume velocity characteristic computed in drawing 7 - drawing 9 at every parting plane 1a using the above-mentioned expression of relations (5) based on a reciprocity theorem, Aggregate value (theoretical value) σ_{Qn} of the volume velocity characteristic for which every parting plane 1a was asked from the velocity of vibration measured directly is similarly expressed with LDV37 to each distance

($h = 1 \text{ mm}, 5 \text{ mm}, 15 \text{ mm}$) of every **between the rectangular vibrating wall 1 and the sounding tube 11 which are sound sources**. In drawing 7 - drawing 9, the experimental value σ_{Q0} is a dashed line, and theoretical-value σ_{Qn} is expressed as the solid line, respectively.

0053 In this experiment, it was checked that the measuring time for calculating the experimental value σ_{Q0} can be shortened about to 1/5 compared with the measuring time (measuring time for calculating theoretical-value σ_{Qn}) which used LDV37.

0054 As shown in drawing 7, in the case of $h = 1 \text{ mm}$ of distance, each peak and a level were in agreement good to 1 kHz, and it was checked that the difference is less than about $\pm 3 \text{ dB}$.

0055 As shown in drawing 8, in the case of $h = 5\text{-mm}$ distance, there was a difference of 4-5 dB below 300 Hz, but in other fields, it was checked to 1 kHz that the difference is less than about $\pm 3 \text{ dB}$.

0056 As shown in drawing 9, in the case of $h = 15\text{-mm}$ distance, the peak up to 1 kHz was mostly in agreement, but on the whole, the level produced a difference of $+5\text{-}+10 \text{ dB}$, and it was checked that especially the difference in 500 Hz or less is large.

0057 It was checked by the above experimental result by the reciprocity theorem that the propagation characteristic H_{pi} which includes the sounding tube 15 from the vibrating wall 1 can be searched for with sufficient accuracy by the simple method using the sounding tube 15 and the microphone 23.

0058 It was checked by using the propagation characteristic H_{pi} searched for and the sound pressure P_0 measured with the sounding tube 11 that it can ask for the volume velocity characteristic of a vibrating structure with sufficient accuracy simple.

0059

Effect of the Invention As explained above, according to the instrumentation method and instrumentation system concerning this invention, the volume velocity Q_0 of a measured plane is called for by a noncontact state from a measured plane. Since a large device is not included on structure, large-scale equipment is not needed, Since it is reflected in the outer wall of the 1st sounding tube, the radiation sound from other than a measured plane can eliminate the influence of the sound source near the measured plane, and further, that it is hard to receive change of the reflectance of a measured plane, and the influence of shape, since adjusting time is unnecessary, it can measure it in a short time.

Field of the Invention This invention relates to the method and device which measure surface vibration of a structure.

Description of the Prior Art In order to measure vibration of a structure generally, the accelerometer is used widely. However, when vibration of a low-mass portion was measured like measurement of surface vibration of the thin gauge structure which noise tends to generate, or measurement of the plane of vibration of a loudspeaker, even if it used the small accelerometer, there was inconvenience that the mass will affect a measurement value.

0003 On the other hand, according to the technique of asking for the velocity of vibration by non-contact, it is possible to perform oscillating measurement of a low-mass portion correctly. As such a technique, the method of using a laser Doppler velocimeter (LDV), the sound intensity method, the acoustical holography method, etc. are known.

Effect of the Invention As explained above, according to the instrumentation method and instrumentation system concerning this invention, the volume velocity Q_0 of a measured plane is called for by a noncontact state from a measured plane. Since a large device is not included on structure, large-scale equipment is not needed, Since it is reflected in the outer wall of the 1st sounding tube, the radiation sound from other than a measured plane can eliminate the influence of the sound source near the measured plane, and further, that it is hard to receive change of the reflectance of a measured plane, and the influence of shape, since adjusting time is unnecessary, it can measure it in a short time.

Problem(s) to be Solved by the Invention Although the sound intensity method is used widely and is well known also as particle-velocity mensuration, when a strong sound source exists near the portion under test, there is a problem that a possibility that a measurement error will increase that it is easy to receive the influence is high. By the method and acoustical holography method for using LDV, there is inconvenience that equipment is large-scale and that it is expensive, in the method of using especially LDV, it is easy to receive change of the reflectance of a portion under test, and the influence of shape, and there is also a problem that measuring time including adjusting time takes great time.

0005 This invention was made in view of the above-mentioned actual condition, and is ****. The purpose does not need equipment, but the influence of the sound source near the measured plane can be eliminated, and it is offer of the oscillating instrumentation method of the structure by non-contact **measurable with a short time** , and a ***** system.

Means for Solving the Problem An oscillating instrumentation method concerning this invention that the above-mentioned purpose should be attained, The 1st sounding tube that has an opening at the end is arranged so that this opening may estrange only the prescribed distance h from a measured plane, The sound pressure P_0 of a sound emitted from said measured plane in a position which estranged only the prescribed distance L_n from said opening within said 1st sounding tube is measured, It arranges so that only said prescribed distance L_n may be estranged from said opening in the 2nd sounding tube that has an opening for a diaphragm which has prescribed area S_i and vibrates by the velocity of vibration V_i at the end, and can demonstrate a propagation characteristic almost equal to said 1st sounding tube, The sound pressure P_i of a sound emitted from said diaphragm in a position which counters with said opening out of said 2nd sounding tube, and estranges only said prescribed distance h from this opening is measured, According to following formula $H_{pi} = S_i \times V_i / P_i$, the propagation characteristic H_{pi} is computed from said area S_i , the velocity of vibration V_i , and the sound pressure P_i , and the volume velocity Q_0 of a measured plane is computed according to following formula $V_0 = P_0 \times H_{pi}$ from this propagation characteristic H_{pi} and the sound pressure P_0 .

0007 An oscillating instrumentation system concerning this invention is provided with the following.

The 1st sound pressure measuring device.

The 2nd sound pressure measuring device.

Operation part.

0008 The 1st sounding tube arranged so that said 1st sound pressure measuring device may have an opening at the end and this opening may estrange only the prescribed distance h from a measured plane, It has the 1st sound pressure test section that measures the sound pressure P_0 of a sound which is arranged in said 1st sounding tube and emitted from said measured plane so that only the prescribed distance L_n may be estranged from said opening. The 2nd sounding tube that said 2nd sound pressure measuring device has an opening at the end, and can demonstrate a propagation characteristic almost equal to said 1st sounding tube, A diaphragm which is arranged in said 2nd sounding tube, has prescribed area S_i , and vibrates by the velocity of vibration V_i so that only said prescribed distance L_n may be estranged from said opening, It has the 2nd sound pressure test section that measures the sound pressure P_i of a sound which is arranged out of said 2nd sounding tube, and is emitted from said diaphragm so that it may counter with this opening in a position which estranged only said prescribed distance h from said opening. Said operation part computes the propagation characteristic H_{pi} according to following formula $H_{pi} = S_i \times V_i / P_i$ from said area S_i , the velocity of vibration V_i , and the sound pressure P_i , and computes the volume velocity Q_0 of a measured plane according to following formula $V_0 = P_0 \times H_{pi}$ from this propagation characteristic H_{pi} and the sound pressure P_0 .

0009 According to the above-mentioned instrumentation method and the instrumentation system, the volume velocity Q_0 of a measured plane is called for by a noncontact state from a measured plane. Since a large device is not included on structure, large-scale equipment is not needed, Since it is reflected in an outer wall of the 1st sounding tube, the radiation sound from

other than a measured plane can eliminate influence of a sound source near the measured plane, and further, that it is hard to receive change of reflectance of a measured plane, and influence of shape, since adjusting time is unnecessary, it can measure it in a short time.

0010In the above-mentioned instrumentation method and an instrumentation system, the other end of said 1st sounding tube may be blockaded. Thereby, influence of a radiation sound from other than a measured plane can be eliminated still more certainly, and the accuracy of measurement improves. The other end of the 2nd sounding tube may be blockaded similarly.

0011In the above-mentioned instrumentation method and an instrumentation system, a sound-absorbing material may be arranged at least to a part which it is on each inner skin of said 1st and 2nd sounding tubes. Thereby, generating of resonance is controlled in the 1st and 2nd sounding tubes, and the accuracy of measurement improves.

0012In an aforesaid measuring method and a measurement system, it may be one sounding tube with which said 1st sounding tube and said 2nd sounding tube are common. Thereby, since the 1st sounding tube and 2nd sounding tube can demonstrate a certainly equal propagation characteristic, the accuracy of measurement improves. Since it is not necessary to form two or more sounding tubes, simplification of a system is attained.

0013As for a cross-section area of said 1st and 2nd sounding tubes, in an aforesaid measuring method and a measurement system, it is preferred to be set up smaller than area which serves as a plane wave to object upper limited frequency. Thereby, since a measured plane and a radiation sound from a diaphragm are spread, respectively, without decreasing inside of the 1st and 2nd sounding tubes, their accuracy of measurement improves.

0014The sound pressure P_i of a sound emitted from said diaphragm on the surface of a rigid high member by position which counters with said opening out of said 2nd sounding tube, and estranges only said prescribed distance h from this opening in an aforesaid measuring method and a measurement system may be measured, Said 1st sounding tube may be arranged along a normal line direction of said measured plane.

0015The velocity of vibration V_0 of a measured plane may be computed according to following formula $V_0 = Q_0 / S_0$ from the volume velocity Q_0 and the area S_0 of a measured plane.

0016

Embodiment of the Invention Hereafter, one embodiment of this invention is described based on a drawing.

0017They are a mimetic diagram showing the state where drawing 1 (a) does not have a mimetic diagram of the 1st sound pressure measuring device of this embodiment, drawing 1 (b) does not have a mimetic diagram of the 2nd sound pressure measuring device of this embodiment, and drawing 2 (a) does not have the 1st sounding tube, and a mimetic diagram showing the state where drawing 2 (b) has the 1st sounding tube.

0018First, the basic constitution of the instrumentation system concerning this embodiment is explained.

0019As shown in drawing 1 (a) and drawing 1 (b), the instrumentation system concerning this embodiment is provided with the following.

The 1st sound pressure measuring device 3.

The 2nd sound pressure measuring device 5.

Operation part 7 and 9.

0020The arbitrary parting planes (measured plane) 1a of the vibrating wall 1 which is a measuring object had the prescribed area S_0 , and the 1st sound pressure measuring device 3 is provided with the 1st sounding tube 11 and 1st microphone (1st sound pressure test section) 13. The 1st sounding tube 11 is a tube-like object made of metal or resin in which the same sectional shape follows linear shape along with the medial axis, and the openings 11a and 11b which present said sectional shape are formed in the both ends. The 1st sounding tube 11 has been arranged along the normal line direction of the parting plane 1a, and the opening 11a of an end has estranged only the prescribed distance h from the parting plane 1a. The microphone 13 is arranged in the 1st sounding tube 11 so that only the prescribed distance L_n may be estranged along with a medial axis from the opening 1a, it measures the sound pressure P_0 of the sound emitted from the parting plane 1a, and outputs it to the operation part 9. The operation part 9 computes and outputs the volume velocity Q_0 and/or the velocity of vibration V_0 by the method of mentioning later.

0021The 2nd sound pressure measuring device 5 is provided with the following.

The 2nd sounding tube 15.

The loudspeaker 19 which has the diaphragm 17.

The rigid high support plate 21.

The 2nd microphone (2nd sound pressure test section) 23.

0022The 2nd sounding tube 15 is a tube-like object made of metal or resin in which the same sectional shape follows linear shape along with the medial axis like the 1st sounding tube 11, and the openings 15a and 15b which present said sectional shape are formed in the both ends. The 2nd sounding tube 15 has shape almost equal to the 1st sounding tube 11, a size, and construction material so that a propagation characteristic almost equal to the 1st sounding tube 11 can be demonstrated. As long as the state where insulation is very high is acquired necessarily identically as for these elements, both construction material may be different.

0023The diaphragm 17 is arranged in the 2nd sounding tube 15 so that only the prescribed distance L_n may be estranged along with a medial axis from the opening 15a of an end. The diaphragm 17 has prescribed area S_i and vibrates by the velocity of vibration V_i . The support plate 21 is arranged almost vertically to the medial axis of the 2nd sounding tube 15 at the position which counters with the opening 15a out of the 2nd sounding tube 15, and estranges only the prescribed distance h from the opening 15a. It is fixed on the outside surface of the support plate 21 in the position which estranged only the prescribed distance h from the opening 15a, and the microphone 23 measures the sound pressure P_i of the sound emitted from the diaphragm 17, and outputs it to the operation part 7. The operation part 7 computes and outputs the propagation characteristic H_{pi} by the method of mentioning later.

0024Thus, the 1st sound pressure measuring device 3 and the 2nd sound pressure measuring device 5 are constituted equivalent about the propagation characteristic of a sound.

0025Next, the instrumentation method concerning this embodiment is explained.

0026The 1st sound pressure measuring device 3 and the 2nd sound pressure measuring device 5, Since it is constituted equivalent about the propagation characteristic of a sound, the volume velocity Q_0 of a reciprocity theorem to the parting plane 1a, The relation of a following formula (1) is materialized between the sound pressure P_0 detected with the microphone 13, the volume velocity Q_i of the diaphragm 17, the sound pressure P_i detected with the microphone 23, and the propagation characteristic H_{pi} .

0027 $Q_0 / P_0 = Q_i / P_i = H_{pi}$ -- (1)

Here, as for the volume velocity Q_0 , the area S_0 and the velocity of vibration V_0 of the parting plane 1a ask for the volume velocity Q_i by area S_i and the velocity of vibration V_i of the diaphragm 17 according to a following formula (2) and (3), respectively.

0028 $Q_0 = S_0 \times V_0$ -- (2)

$Q_i = S_i \times V_i$ -- (3)

Therefore, the following formula (4), (5), and (6) is called for from a formula (1), (2), and (3).

0029 $H_{pi} = S_i \times V_i / P_i$ -- (4)

$Q_0 = P_0 \times H_{pi}$ -- (5)

$V_0 = P_0 \times H_{pi} / S_0$ -- (6)

When measuring the volume velocity Q_0 and/or the velocity of vibration V_0 of a sound which are emitted from the parting plane 1a, first, the 2nd sound pressure measuring device 5 is used, the sound pressure P_i of the sound emitted from the loudspeaker 19 (diaphragm 17) is detected with the microphone 23, and it is inputted into the operation part 7. Area S_i and the velocity of vibration V_i of the diaphragm 17 are beforehand inputted into the operation part 7, and are memorized, and the propagation characteristic H_{pi} is computed according to a formula (4) from these P_i , S_i , and V_i .

0030Next, the 1st sound pressure measuring device 3 is used, the sound pressure P_0 of the sound emitted from the parting plane 1a is detected with the microphone 13, and it is inputted into the operation part 9. The propagation characteristic H_{pi} computed by the operation part 7 and the area S_0 of the parting plane 1a are beforehand inputted into the operation part 9, and are memorized, and the volume velocity Q_0 and/or the velocity of vibration V_0 of the parting plane 1a are computed according to these P_0 , H_{pi} , and S_0 to a formula (5) and/or (6). When only the volume velocity Q_0 is computed, the area S_0 of the parting plane 1a does not need to be inputted into the operation part 9.

0031According to such an instrumentation method and an instrumentation system, it can ask for the volume velocity Q_0 and/or the velocity of vibration V_0 of the parting plane 1a by a noncontact state from the parting plane 1a.

0032Since a large device is not included on structure, large-scale equipment is not needed.

0033The radiation sound from other than parting plane 1a is reflected in the outer wall of the 1st sounding tube 11. For example, if sound pressure P_m near the parting plane 1a is measured

with the microphone 25 in the state where the 1st sounding tube 11 is not formed as shown in drawing 2 (a), sound pressure P_m detected will be influenced by leak lump of the oscillating radiation sound P_j from an adjoining parting plane. For this reason, detection of the radiation sound only from the parting plane 1a which is a measuring object is difficult. On the other hand, as shown in drawing 2 (b), where the 1st sounding tube 11 is formed. It is reflected in the outer wall of the 1st sounding tube 11, and the radiation sound from other than parting plane 1a is spread inside the sounding tube 11 by only the plane wave according to the velocity of vibration V_0 of the parting plane 1a, and can measure the sound pressure P_0 with the microphone 11. That is, the influence of the sound source near the parting plane 1a can be eliminated.

0034 That it is hard to receive change of the reflectance of a measured plane (parting plane 1a), and the influence of shape, since adjusting time is unnecessary, it can measure extremely in a short time.

0035 The sectional shape in particular of the 1st sounding tube 11 and the 2nd sounding tube 15 is not limited, and shape with various circular, rectangles, etc. may be applied.

0036 The 1st sounding tube 11 and 2nd sounding tube 15 may be one common sounding tube. Thereby, since the 1st sounding tube and 2nd sounding tube can demonstrate a certainly equal propagation characteristic, the accuracy of measurement improves. Since it is not necessary to form two or more sounding tubes, simplification of a system is attained.

0037 The cross-section area of the 1st and 2nd sounding tubes 11 and 15, It is preferred that the sectional shape of being set up smaller than the area which serves as a plane wave to object upper limited frequency, for example, the inner skin of the 1st and 2nd sounding tubes 11 and 15, is set as the size and shape which contain thoroughly the shape almost equal to a periphery edge or this shape of the parting plane 1a inside. Thereby, since the parting plane 1a and the radiation sound from the diaphragm 17 are spread, respectively, without decreasing the inside of the 1st and 2nd sounding tubes 11 and 15, their accuracy of measurement improves.

0038 By sticking and arranging the sound-absorbing material 27 on each inner skin of the 1st and 2nd sounding tubes 11 and 15, generating of resonance is controlled in the 1st and 2nd sounding tubes 11 and 15, and the accuracy of measurement improves. It is demonstrated even if the depressor effect of resonance is not established throughout each inner skin of the 1st and 2nd sounding tubes 11 and 15, For example, if it provides in the field of a semicircle as shown in drawing 3 (a) when the sounding tubes 11 and 15 are cylindrical, the effect will fully be acquired, and if it provides throughout one inner surface among four inner surfaces as shown in drawing 3 (b) when it is rectangular cylinder form, the effect will fully be acquired. Since the composition of the 2nd sounding tube 15 is almost the same as that of the 1st sounding tube 11, the graphic display is omitted.

0039 By blockading the other end 11b of the 1st sounding tube 11, the influence of the radiation sound from other than parting plane 1a can be eliminated still more certainly, and the accuracy of measurement improves. In this case, although it is also possible to blockade the other end 11b by the sounding tube 11, the lid formed in one, etc., it is most preferred for it to be more desirable to blockade with the sound-absorbing material 29, as shown in drawing 4, and to provide with the sound-absorbing material 27 on inner skin further. Also in the 2nd sounding tube 15, influence can be eliminated from the exterior by blockading similarly the other end 15b of the 2nd sounding tube 15.

0040 Next, the conducted experiment using the instrumentation system concerning this embodiment is explained.

0041 As shown in drawing 5 (a), in the 1st sound pressure measuring device 3 used in the experiment, the vibrating wall 1 which is a noise source is formed in the shape of a rectangular plate object of a 2-mm-thick griddle, and is being fixed to the buck 31. The buck 31 is formed in the shape of **which has an open face on the whole surface** a box, and it is arranged so that an open face may be horizontally suitable. The vibrating wall 1 is concluded by the edge part of the open face with two or more bolts so that the open face of the buck 31 may be blockaded. The loudspeaker 33 is being fixed on the field which carries out for relativity to the vibrating wall 1 in the buck 31. The buck 31 is formed of the griddle which has 10 sufficient mm in thickness so that the sound emitted from the loudspeaker 33 may be emitted by sound excitation only from the vibrating wall 1. 20 division (four rows by five rows) of the outside surface of the vibrating wall 1 which is a sound source is carried out, and the one parting plane 1a is set as the approximately square of 80 mm x 80 mm.

0042 The 1st sounding tube 11 is formed in the shape of **which has sectional shape and a size almost equal to the parting plane 1a** a rectangle barrel, and is attached to the traverse

device besides a graphic display. The traverse device is supporting the 1st sounding tube 11 to the parting plane 1a, enabling free movement in a parallel direction and a vertical direction, where the normal line direction of the outside surface (parting plane 1a) of the vibrating wall 1 is met. Length L of the sounding tube 11 is set as 40 mm so that the sound pressure in the sounding tube 11 may not be influenced by surroundings lump. The distance Ln from the opening 11a of the sounding tube 11 to the microphone 13 is set as 30 mm so that the radiation sound from the vibrating wall 1 (parting plane 1a) may serve as a plane wave certainly.

0043 Measurement of the radiation sound from the vibrating wall 1 moved the 1st sounding tube 11 to each parting plane 1a with a traverse device, and was performed by measuring the sound pressure P_i in the sounding tube 11 with the microphone 13 on the basis of the input voltage E from the power amplification 39 to the loudspeaker 33. Under the present circumstances, the position of the sounding tube 11 to each parting plane 1a was adjusted so that the sounding tube 11 might be arranged along the normal line direction of each parting plane 1a and the opening 11a of the end of the sounding tube 11 might estrange only the prescribed distance h from each parting plane 1a. About this distance h, it measured about three conditions (1 mm, 5 mm, and 15 mm).

0044 Simultaneously, for comparison with the result obtained by this experiment, the reflection type besides a graphic display was stuck on each parting plane 1a, and the velocity of vibration was measured, adjusting an optic axis to each parting plane 1a of every using the noncontact laser vibration meter (LDV) 37. LDV37 was used in order to eliminate the influence of the mass by an accelerometer.

0045 As shown in drawing 5 (b), in the 2nd sound pressure measuring device 5 used for the experiment, the support plate 21 is formed with iron material with a thickness of 30 mm which has sufficient rigidity. The microphone 23 is embedded at the support plate 21 so that it may be located on the outside surface of the support plate 21 in which the sound-collecting part carries out for relativity to the opening 15a of the end of the 2nd sounding tube 15. The 2nd sounding tube 15 has the 1st size and shape almost equal to the sounding tube 11, and it is arranged so that the normal line direction of opposite *Perilla frutescens* (L.) Britton var. *crispa* (Thunb.) Decne. may be met at the support plate 21. The area of the diaphragm besides the graphic display of the loudspeaker 19 in the 2nd sounding tube 15 is beforehand set as the prescribed area S_0 .

0046 Measurement of the radiation sound from the loudspeaker 19 was performed by measuring the sound pressure P_0 of the radiation sound from the loudspeaker 19 with the microphone 23 on the basis of the input voltage e from the power amplification 43 to the loudspeaker 19. About the distance h along said normal line direction of the microphone 23 and the opening 15a of the sounding tube 15, it measured about three conditions (1 mm, 5 mm, and 15 mm).

0047 Simultaneously, it measured by LDV besides a graphic display of the velocity of vibration V_0 of the diaphragm besides the graphic display in the loudspeaker 19. Having used LDV has the dramatically small mass of a diaphragm, and it is easy to generate partial vibration and rolling in response to the influence by the weight in a contact type.

0048 The sound pressure P_i of the radiation sound from the loudspeaker 19 measured with the microphone 23 is inputted into the high speed operation device (FFT) 41 as the operation part 7. The velocity of vibration V_i measured by the area S_i and LDV of the diaphragm 17 is beforehand inputted into FFT41, and is memorized, and the propagation characteristic H_{pi} is computed and outputted to it at each distance h of every according to said formula (4) from P_i , S_i , and V_i .

0049 The sound pressure P_0 of the radiation sound from the parting plane 1a measured with the microphone 13 of the 1st sound pressure measuring device 3 is inputted into the high speed operation device (FFT) 35 as the operation part 9. The propagation characteristic H_{pi} computed by FFT41 and the area S_0 of the parting plane 1a are beforehand inputted into FFT35, and are memorized, The volume velocity Q_0 is computed by every parting plane 1a according to these P_0 , H_{pi} , and S_0 to said formula (5) and/or (6), and the aggregate value σQ_0 is outputted eventually. The velocity of vibration measured by LDV37 is also inputted into FFT35. In FFT35, by multiplying the velocity of vibration measured by LDV37 by the area S_0 of the parting plane 1a, the theoretical value of the volume velocity in this experiment is computed by every parting plane 1a, and the aggregate value σQ_t is outputted eventually.

0050 Next, the result of this experiment is explained based on drawing 6 - drawing 9.

0051 The propagation characteristic H_p of each distance h of every **which was outputted**

from **FFT41** is expressed to drawing 6. It was checked that a level also increases, when the frequency characteristic showed the identical trend and its distance h increased, although there was a level difference by the distance h as shown in drawing 6.

0052The aggregate value (experimental value) σQ_0 of the volume velocity characteristic computed in drawing 7 - drawing 9 at every parting plane 1a using the above-mentioned expression of relations (5) based on a reciprocity theorem, Aggregate value (theoretical value) σQ_n of the volume velocity characteristic for which every parting plane 1a was asked from the velocity of vibration measured directly is similarly expressed with LDV37 to each distance ($h = 1 \text{ mm}, 5 \text{ mm}, 15 \text{ mm}$) of every **between the rectangular vibrating wall 1 and the sounding tube 11 which are sound sources**. In drawing 7 - drawing 9, the experimental value σQ_0 is a dashed line, and theoretical-value σQ_n is expressed as the solid line, respectively.

0053In this experiment, it was checked that the measuring time for calculating the experimental value σQ_0 can be shortened about to 1/5 compared with the measuring time (measuring time for calculating theoretical-value σQ_n) which used LDV37.

0054As shown in drawing 7, in the case of $h = 1 \text{ mm}$ of distance, each peak and a level were in agreement good to 1 kHz, and it was checked that the difference is less than about **3 dB.

0055As shown in drawing 8, in the case of $h = 5\text{-mm}$ distance, there was a difference of 4-5 dB below 300 Hz, but in other fields, it was checked to 1 kHz that the difference is less than about **3 dB.

0056As shown in drawing 9, in the case of $h = 15\text{-mm}$ distance, the peak up to 1 kHz was mostly in agreement, but on the whole, the level produced a difference of +5-+10 dB, and it was checked that especially the difference in 500 Hz or less is large.

0057It was checked by the above experimental result by the reciprocity theorem that the propagation characteristic H_{pi} which includes the sounding tube 15 from the vibrating wall 1 can be searched for with sufficient accuracy by the simple method using the sounding tube 15 and the microphone 23.

0058It was checked by using the propagation characteristic H_{pi} searched for and the sound pressure P_0 measured with the sounding tube 11 that it can ask for the volume velocity characteristic of a vibrating structure with sufficient accuracy simple.

Brief Description of the Drawings

Drawing 1Drawing 1 (a) is a mimetic diagram of the 1st sound pressure measuring device of this embodiment, and drawing 1 (b) is a mimetic diagram of the 2nd sound pressure measuring device of this embodiment.

Drawing 2Drawing 2 (a) is a mimetic diagram showing the state where there is no 1st sounding tube, and a mimetic diagram showing the state where drawing 2 (b) has the 1st sounding tube.

Drawing 3The sectional view and drawing 3 (b) in which the state where drawing 3 (a) stuck silencing materials on the inner skin of a cylindrical sounding tube is shown are a sectional view showing the state where silencing materials were stuck on the inner surface of a rectangle barrel-like sounding tube.

Drawing 4The other end is a sectional view showing the sounding tube blockaded with silencing materials.

Drawing 5The mimetic diagram of the experimental device corresponding to drawing 1 (a) in drawing 5 (a) and drawing 5 (b) are the mimetic diagrams of the experimental device corresponding to drawing 1 (b).

Drawing 6It is a figure showing the propagation characteristic of each distance h of every **which was called for by the experiment concerning this embodiment**.

Drawing 7It is a figure showing the experimental value and theoretical value of an aggregate value of the volume velocity characteristic in the case of $h = 1 \text{ mm}$ of distance.

Drawing 8It is a figure showing the experimental value and theoretical value of an aggregate value of the volume velocity characteristic in the case of $h = 5\text{-mm}$ distance.

Drawing 9It is a figure showing the experimental value and theoretical value of an aggregate value of the volume velocity characteristic in the case of $h = 15\text{-mm}$ distance.

Description of Notations

1 Vibrating wall

1a The parting plane of a vibrating wall (measured plane)

3 The 1st sound pressure measuring device
5 The 2nd sound pressure measuring device
7 Operation part
9 Operation part
11 The 1st sounding tube
13 Microphone (1st sound pressure test section)
15 The 2nd sounding tube
17 Diaphragm
19 Loudspeaker
23 Microphone (2nd sound pressure test section)

Drawing 1

For drawings please refer to the original document.

Drawing 2

For drawings please refer to the original document.

Drawing 3

For drawings please refer to the original document.

Drawing 4

For drawings please refer to the original document.

Drawing 6

For drawings please refer to the original document.

Drawing 5

For drawings please refer to the original document.

Drawing 7

For drawings please refer to the original document.

Drawing 8

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Drawing 9

For drawings please refer to the original document.

For drawings please refer to the original document.

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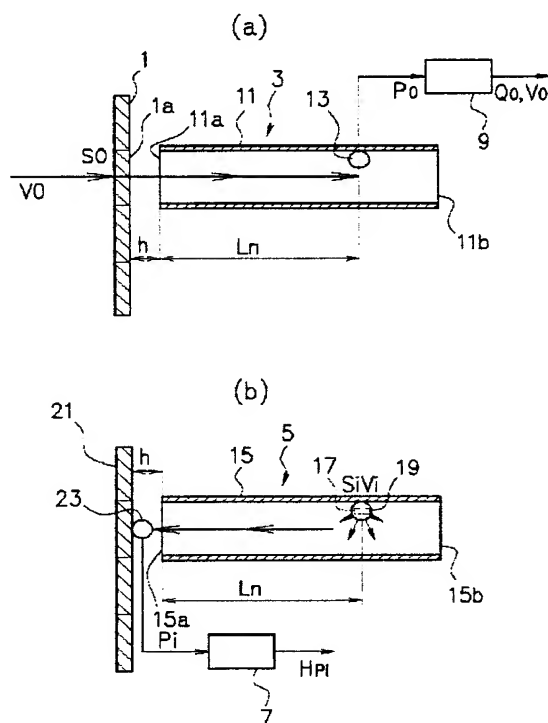
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(54)【発明の名称】 振動計測方法及び振動計測システム

(57)【要約】 (修正有)

【課題】 簡単な設備で、被測定面近傍の音源の影響を排除することができ、且つ短時間で測定可能な非接触による振動計測方法の提供。

【解決手段】 第1の音響管11を開口11aが被測定面1aから距離hだけ離間するように配置し、第1の音響管11内で開口11aから所定距離Lnだけ離間した位置にて被測定面1aから発せられる音の音圧P0を測定し、所定面積Siを有し振動速度Viで振動する振動板17を、第1の音響管11とはほぼ等しい伝搬特性を発揮し得る第2の音響管15内に開口15aから所定距離Lnだけ離間するように配置し、第2の音響管15外で開口15aと対向し且つ開口15aから所定距離hだけ離間する位置にて振動板17から発せられる音の音圧Piを測定し、面積Siと振動速度Viと音圧Piとから $H_{pi} = S_i \times V_i / P_i$ に従って伝搬特性Hpiを算出し、該伝搬特性Hpiと音圧P0とから $V_0 = P_0 \times H_{pi}$ に従って被測定面の体積速度Q0を算出する。



【特許請求の範囲】

【請求項 1】 一端に開口を有する第 1 の音響管を該開口が被測定面から所定距離 h だけ離間するように配置し、

前記第 1 の音響管内で前記開口から所定距離 L_n だけ離間した位置にて前記被測定面から発せられる音の音圧 P_0 を測定し、

所定面積 S_i を有し振動速度 V_i で振動する振動板を、一端に開口を有し前記第 1 の音響管とほぼ等しい伝搬特性を発揮し得る第 2 の音響管内に前記開口から前記所定距離 L_n だけ離間するように配置し、

前記第 2 の音響管外で前記開口と対向し且つ該開口から前記所定距離 h だけ離間する位置にて前記振動板から発せられる音の音圧 P_i を測定し、

前記面積 S_i と振動速度 V_i と音圧 P_i とから次式

$$H_{pi} = S_i \times V_i / P_i$$

に従って伝搬特性 H_{pi} を算出し、

前記伝搬特性 H_{pi} と音圧 P_0 とから次式

$$Q_0 = P_0 \times H_{pi}$$

に従って被測定面の体積速度 Q_0 を算出することを特徴とする振動計測方法。

【請求項 2】 請求項 1 に記載の振動計測方法であって、

前記第 1 の音響管の他端は、閉塞されていることを特徴とする振動計測方法。

【請求項 3】 請求項 1 又は請求項 2 に記載の振動計測方法であって、

前記第 1 及び第 2 の音響管の各内周面上の少なくとも一部には、吸音材が配置されていることを特徴とする振動計測方法。

【請求項 4】 一端に開口を有し該開口が被測定面から所定距離 h だけ離間するように配置された第 1 の音響管と、前記開口から所定距離 L_n だけ離間するように前記第 1 の音響管内に配置され前記被測定面から発せられる音の音圧 P_0 を測定する第 1 の音圧測定部と、を有する第 1 の音圧測定装置と、

一端に開口を有し前記第 1 音響管とほぼ等しい伝搬特性を発揮し得る第 2 の音響管と、前記開口から前記所定距離 L_n だけ離間するように前記第 2 の音響管内に配置され所定面積 S_i を有し振動速度 V_i で振動する振動板と、前記開口から前記所定距離 h だけ離間した位置で該開口と対向するように前記第 2 の音響管外に配置され前記振動板から発せられる音の音圧 P_i を測定する第 2 の音圧測定部と、を有する第 2 の音圧測定装置と、

前記面積 S_i と振動速度 V_i と音圧 P_i とから次式 $H_{pi} = S_i \times V_i / P_i$ に従って伝搬特性 H_{pi} を算出し、該伝搬特性 H_{pi} と音圧 P_0 とから次式

$$V_0 = P_0 \times H_{pi}$$

に従って被測定面の体積速度 Q_0 を算出する演算部と、

1 10 20 30 40 50

を備えたことを特徴とする振動計測システム。

【請求項 5】 請求項 4 に記載の振動計測システムであって、

前記第 1 の音響管の他端は、閉塞されていることを特徴とする振動計測システム。

【請求項 6】 請求項 4 又は請求項 5 に記載の振動計測システムであって、

前記第 1 及び第 2 の音響管の各内周面上の少なくとも一部には、吸音材が配置されていることを特徴とする振動計測システム。

【発明の詳細な説明】

【0 0 0 1】

【発明の属する技術分野】 本発明は、構造体の表面振動を計測する方法及び装置に関する。

【0 0 0 2】

【従来の技術】 一般に構造物の振動を計測するには、加速度計が広く用いられている。しかし、騒音の発生し易い薄板構造の表面振動の計測やスピーカの振動面の計測などのように質量の小さい部分の振動を計測する場合、小型の加速度計を用いてもその質量が計測値に影響を与えてしまうという不都合があった。

【0 0 0 3】 これに対し、振動速度を非接触で求める手法によれば、質量の小さい部分の振動計測を正確に行うことが可能である。このような手法として、レーザー・ドップラー速度計 (LDV) を用いる方法や、音響インテンシティ法や、音響ホログラフィ法などが知られている。

【0 0 0 4】

【発明が解決しようとする課題】 音響インテンシティ法は、広く利用されており、粒子速度計測法としても良く知られているが、被測定部分の近傍に強い音源が存在すると、その影響を受けやすく計測誤差が増大する可能性が高いという問題がある。また、LDV を用いる方法や音響ホログラフィ法では、設備が大掛かりで高価であるという不都合があり、特に LDV を用いる方法では、被測定部分の反射率の変化や形状の影響を受け易く、調整時間を含めた測定時間に多大な時間を要するという問題もある。

【0 0 0 5】 本発明は上記の実情に鑑みてなされたものであって、大掛かりな設備を必要とせず、被測定面近傍の音源の影響を排除することができ、且つ短時間で測定可能な非接触による構造体の振動計測方法及び振動計測システムの提供を目的とするものである。

【0 0 0 6】

【課題を解決するための手段】 上記目的を達成すべく、本発明に係る振動計測方法は、一端に開口を有する第 1 の音響管を該開口が被測定面から所定距離 h だけ離間するように配置し、前記第 1 の音響管内で前記開口から所定距離 L_n だけ離間した位置にて前記被測定面から発せられる音の音圧 P_0 を測定し、所定面積 S_i を有し振動

速度 V_i で振動する振動板を、一端に開口を有し前記第 1 の音響管とほぼ等しい伝搬特性を発揮し得る第 2 の音響管内に前記開口から前記所定距離 L_n だけ離間するように配置し、前記第 2 の音響管外で前記開口と対向し且つ該開口から前記所定距離 h だけ離間する位置にて前記振動板から発せられる音の音圧 P_i を測定し、前記面積 S_i と振動速度 V_i と音圧 P_i とから次式

$$H_{pi} = S_i \times V_i / P_i$$

に従って伝搬特性 H_{pi} を算出し、該伝搬特性 H_{pi} と音圧 P_0 とから次式

$$V_0 = P_0 \times H_{pi}$$

に従って被測定面の体積速度 Q_0 を算出するものである。

【0007】本発明に係る振動計測システムは、第 1 の音圧測定装置と、第 2 の音圧測定装置と、演算部とを備えている。

【0008】前記第 1 の音圧測定装置は、一端に開口を有し該開口が被測定面から所定距離 h だけ離間するように配置された第 1 の音響管と、前記開口から所定距離 L_n だけ離間するように前記第 1 の音響管内に配置され前記被測定面から発せられる音の音圧 P_0 を測定する第 1 の音圧測定部と、を有する。前記第 2 の音圧測定装置は、一端に開口を有し前記第 1 の音響管とほぼ等しい伝搬特性を発揮し得る第 2 の音響管と、前記開口から前記所定距離 L_n だけ離間するように前記第 2 の音響管内に配置され所定面積 S_i を有し振動速度 V_i で振動する振動板と、前記開口から前記所定距離 h だけ離間した位置で該開口と対向するように前記第 2 の音響管外に配置され前記振動板から発せられる音の音圧 P_i を測定する第 2 の音圧測定部と、を有する。前記演算部は、前記面積 S_i と振動速度 V_i と音圧 P_i とから次式

$$H_{pi} = S_i \times V_i / P_i$$

に従って伝搬特性 H_{pi} を算出し、該伝搬特性 H_{pi} と音圧 P_0 とから次式

$$V_0 = P_0 \times H_{pi}$$

に従って被測定面の体積速度 Q_0 を算出する。

【0009】上記計測方法及び計測システムによれば、被測定面に対して非接触状態で被測定面の体積速度 Q_0 が求められる。また、構造上大きな装置を含まないため大掛かりな設備を必要とせず、被測定面以外からの放射音は第 1 の音響管の外壁で反射されるので被測定面近傍の音源の影響を排除することができ、さらに、被測定面の反射率の変化や形状の影響を受け難く調整時間が不要であるため短時間で測定することができる。

【0010】上記計測方法及び計測システムにおいて、前記第 1 の音響管の他端を閉塞しても良い。これにより、被測定面以外からの放射音の影響をさらに確実に排除することができ、測定精度が向上する。また、第 2 の音響管の他端を同様に閉塞しても良い。

【0011】上記計測方法及び計測システムにおいて、

前記第 1 及び第 2 の音響管の各内周面上の少なくとも一部に、吸音材を配置しても良い。これにより、第 1 及び第 2 の音響管内において共鳴の発生が抑制され、測定精度が向上する。

【0012】上記測定方法及び測定システムにおいて、前記第 1 の音響管と前記第 2 の音響管とが共通する 1 つの音響管であっても良い。これにより、第 1 の音響管と第 2 の音響管とが確実に等しい伝搬特性を発揮し得るので、測定精度が向上する。また、複数の音響管を設ける必要がないので、システムの簡素化が図られる。

【0013】上記測定方法及び測定システムにおいて、前記第 1 及び第 2 の音響管の断面積は、対象上限周波数に対して平面波となる面積よりも小さく設定されることが好ましい。これにより、被測定面及び振動板からの放射音はそれぞれ第 1 及び第 2 の音響管内を減衰することなく伝搬されるので、測定精度が向上する。

【0014】上記測定方法及び測定システムにおいて、前記第 2 の音響管外で前記開口と対向し且つ該開口から前記所定距離 h だけ離間する位置に剛性の高い部材の表面上で前記振動板から発せられる音の音圧 P_i を測定しても良く、また、前記第 1 の音響管を前記被測定面の法線方向に沿って配置しても良い。

【0015】さらに、被測定面の振動速度 V_0 を体積速度 Q_0 と被測定面の面積 S_0 とから次式

$$V_0 = Q_0 / S_0$$

に従って算出しても良い。

【0016】

【発明の実施の形態】以下、本発明の一実施形態を、図面に基づいて説明する。

【0017】図 1 (a) は本実施形態の第 1 の音圧測定装置の模式図、図 1 (b) は本実施形態の第 2 の音圧測定装置の模式図、図 2 (a) は第 1 の音響管がない状態を示す模式図、図 2 (b) は第 1 の音響管がある状態を示す模式図である。

【0018】まず、本実施形態に係る計測システムの基本構成について説明する。

【0019】図 1 (a) 及び図 1 (b) に示すように、本実施形態に係る計測システムは、第 1 の音圧測定装置 3 と、第 2 の音圧測定装置 5 と、演算部 7、9 とを備えている。

【0020】測定対象である振動壁 1 の任意の分割面（被測定面）1 a は所定面積 S_0 を有し、第 1 の音圧測定装置 3 は第 1 の音響管 1 1 と第 1 のマイクロホン（第 1 の音圧測定部）1 3 とを備えている。第 1 の音響管 1 1 は、同一の断面形状がその中心軸に沿って直線状に連続する金属又は樹脂製の筒状体であり、その両端には前記断面形状を呈する開口 1 1 a、1 1 b が形成されている。第 1 の音響管 1 1 は分割面 1 a の法線方向に沿って配置され、一端の開口 1 1 a は分割面 1 a から所定距離 h だけ離間している。マイクロホン 1 3 は、開口 1 a か

ら中心軸に沿って所定距離 L_n だけ離間するように第 1 の音響管 11 内に配置され、分割面 1 a から発せられる音の音圧 P_0 を測定して演算部 9 へ出力する。演算部 9 は、後述する方法によって体積速度 Q_0 及び／又は振動速度 V_0 を算出し出力する。

【0021】第 2 の音圧測定装置 5 は、第 2 の音響管 15 と、振動板 17 を有するスピーカ 19 と、剛性の高い支持板 21 と、第 2 のマイクロホン（第 2 の音圧測定部）23 とを備えている。

【0022】第 2 の音響管 15 は、第 1 の音響管 11 と同様に、同一の断面形状がその中心軸に沿って直線状に連続する金属又は樹脂製の筒状体であり、その両端には前記断面形状を呈する開口 15 a、15 b が形成されている。第 2 の音響管 15 は、第 1 の音響管 11 とほぼ等しい伝搬特性を発揮し得るように、第 1 の音響管 11 とほぼ等しい形状、大きさ、及び材質を有している。なお、これらの要素は必ずしも同一である必要はなく、例えば遮音性が極めて高い状態が得られれば両者の材質は相違していても構わない。

【0023】振動板 17 は、一端の開口 15 a から中心軸に沿って所定距離 L_n だけ離間するように第 2 の音響管 15 内に配置されている。振動板 17 は、所定面積 S_i を有し、振動速度 V_i で振動する。支持板 21 は、第 2 の音響管 15 外で開口 15 a と対向し且つ開口 15 a から所定距離 h だけ離間する位置に、第 2 の音響管 15 の中心軸に対してほぼ垂直に配置されている。マイクロホン 23 は、開口 15 a から所定距離 h だけ離間した位置で支持板 21 の外面上に固定され、振動板 17 から発せられる音の音圧 P_i を測定して演算部 7 へ出力する。演算部 7 は、後述する方法によって伝搬特性 H_{pi} を算出し出力する。

【0024】このように、第 1 の音圧測定装置 3 と第 2 の音圧測定装置 5 とは、音の伝搬特性に関して等価に構成されている。

【0025】次に、本実施形態に係る計測方法について説明する。

【0026】第 1 の音圧測定装置 3 と第 2 の音圧測定装置 5 とは、音の伝搬特性に関して等価に構成されているため、相反定理から、分割面 1 a の体積速度 Q_0 、マイクロホン 13 によって検出される音圧 P_0 、振動板 17 の体積速度 Q_i 、マイクロホン 23 によって検出される音圧 P_i 、及び伝搬特性 H_{pi} との間には、次式（1）の関係が成立する。

$$Q_0 / P_0 = Q_i / P_i = H_{pi} \quad \cdots (1)$$

ここで、体積速度 Q_0 は、分割面 1 a の面積 S_0 及び振動速度 V_0 により、体積速度 Q_i は、振動板 17 の面積 S_i 及び振動速度 V_i により、それぞれ次式（2）、（3）に従って求められる。

$$Q_0 = S_0 \times V_0 \quad \cdots (2)$$

$$Q_i = S_i \times V_i \quad \cdots (3)$$

従って、式（1）、（2）、（3）から、次式（4）、（5）、（6）が求められる。

$$H_{pi} = S_i \times V_i / P_i \quad \cdots (4)$$

$$Q_0 = P_0 \times H_{pi} \quad \cdots (5)$$

$$V_0 = P_0 \times H_{pi} / S_0 \quad \cdots (6)$$

分割面 1 a から放射される音の体積速度 Q_0 及び／又は振動速度 V_0 を測定する場合、まず、第 2 の音圧測定装置 5 が使用され、スピーカ 19（振動板 17）から放射される音の音圧 P_i がマイクロホン 23 によって検出されて演算部 7 へ入力される。演算部 7 には、振動板 17 の面積 S_i 及び振動速度 V_i が予め入力され記憶されており、これら P_i 、 S_i 、 V_i から式（4）に従って伝搬特性 H_{pi} が算出される。

【0030】次に、第 1 の音圧測定装置 3 が使用され、分割面 1 a から放射される音の音圧 P_0 がマイクロホン 13 によって検出されて演算部 9 へ入力される。演算部 9 には、演算部 7 によって算出された伝搬特性 H_{pi} 及び分割面 1 a の面積 S_0 が予め入力され記憶されており、これら P_0 、 H_{pi} 、 S_0 から式（5）及び／又は（6）に従って分割面 1 a の体積速度 Q_0 及び／又は振動速度 V_0 が算出される。なお、体積速度 Q_0 のみが算出される場合には、分割面 1 a の面積 S_0 は演算部 9 に入力されなくても良い。

【0031】このような計測方法及び計測システムによれば、分割面 1 a に対して非接触状態で分割面 1 a の体積速度 Q_0 及び／又は振動速度 V_0 を求めることができる。

【0032】また、構造上大きな装置を含まないため、大掛かりな設備を必要とすることがない。

【0033】また、分割面 1 a 以外からの放射音は、第 1 の音響管 11 の外壁で反射される。例えば、図 2（a）に示すように、第 1 の音響管 11 を設けない状態で、分割面 1 a の近傍の音圧 P_m をマイクロホン 25 によって計測すると、検出される音圧 P_m は隣接する分割面からの振動放射音 P_j の漏れ込みの影響を受ける。このため、測定対象である分割面 1 a のみからの放射音の検出が難しい。これに対し、図 2（b）に示すように、第 1 の音響管 11 を設けた状態では、分割面 1 a 以外からの放射音は第 1 の音響管 11 の外壁で反射され、分割面 1 a の振動速度 V_0 に応じた平面波のみが音響管 11 の内部に伝搬され、マイクロホン 11 によってその音圧 P_0 を計測することができる。すなわち、分割面 1 a 近傍の音源の影響を排除することができる。

【0034】さらに、被測定面（分割面 1 a）の反射率の変化や形状の影響を受け難く調整時間が不要であるため、極めて短時間で測定することができる。

【0035】なお、第 1 の音響管 11 及び第 2 の音響管 15 の断面形状は、特に限定されるものではなく、円形、矩形等の様々な形状が適用され得る。

【0036】また、第 1 の音響管 11 と第 2 の音響管 1

5 とは、共通する 1 つの音響管であっても良い。これにより、第 1 の音響管と第 2 の音響管とが確実に等しい伝搬特性を発揮し得るので、測定精度が向上する。また、複数の音響管を設ける必要がないので、システムの簡素化が図られる。

【0037】また、第 1 及び第 2 の音響管 11, 15 の断面積は、対象上限周波数に対して平面波となる面積よりも小さく設定されていること、例えば、第 1 及び第 2 の音響管 11, 15 の内周面の断面形状が分割面 1 a の外周縁とほぼ等しい形状又はこの形状を完全に内側に含む大きさ及び形状に設定されていることが好ましい。これにより、分割面 11 a 及び振動板 17 からの放射音はそれぞれ第 1 及び第 2 の音響管 11, 15 内を減衰することなく伝搬されるので、測定精度が向上する。

【0038】また、第 1 及び第 2 の音響管 11, 15 の各内周面上に吸音材 27 を貼着して配置することにより、第 1 及び第 2 の音響管 11, 15 内において共鳴の発生が抑制され、測定精度が向上する。共鳴の抑制効果は、第 1 及び第 2 の音響管 11, 15 の各内周面の全域に設けられていなくても発揮され、例えば、音響管 11, 15 が円筒状の場合は図 3 (a) に示すように半周の領域に設ければその効果が十分に得られ、矩形筒状の場合は図 3 (b) に示すように 4 箇所の内面のうち 1 箇所の内面全域に設ければその効果が十分に得られる。なお、第 2 の音響管 15 の構成は第 1 の音響管 11 とほぼ同様であるため、その図示を省略している。

【0039】さらに、第 1 の音響管 11 の他端 11 b を閉塞することにより、分割面 1 a 以外からの放射音の影響をさらに確実に排除することができ、測定精度が向上する。この場合、他端 11 b を音響管 11 と一体的に形成された蓋体等によって閉塞することも可能であるが、図 4 に示すように吸音材 29 によって閉塞する方がより好ましく、さらに内周面上の吸音材 27 と共に設けることが最も好ましい。また、第 2 の音響管 15 の他端 15 b を同様に閉塞することにより、第 2 の音響管 15 においても外部から影響を排除することができる。

【0040】次に、本実施形態に係る計測システムを用いた行った実験について説明する。

【0041】図 5 (a) に示すように、実験で使用された第 1 の音圧測定装置 3 では、騒音源である振動壁 1 は、厚さ 2 mm の鉄板により矩形板体状に形成され、支持台 31 に固定されている。支持台 31 は、一面に開放面を有する箱体状に形成され、開放面が水平方向を向くように配置されている。振動壁 1 は、支持台 31 の開放面を閉塞するように開放面の周縁部分に複数のホルトによって締結されている。スピーカ 33 は、支持台 31 内の振動壁 1 と相対向する面上に固定されている。支持台 31 は、スピーカ 33 から放射された音が音響加振により振動壁 1 のみから放射されるように、十分な厚さ 10 mm を有する鉄板によって形成されている。音源である振動

壁 1 の外面は 20 分割（縦 4 列×横 5 列）され、一つの分割面 1 a は 80 mm×80 mm の略正方形に設定されている。

【0042】第 1 の音響管 11 は、分割面 1 a とほぼ等しい断面形状及び大きさを有する矩形筒体状に形成され、図示外のトラバース装置に取り付けられている。トラバース装置は、第 1 の音響管 11 を、振動壁 1 の外面（分割面 1 a）の法線方向に沿った状態で分割面 1 a に対して平行な方向及び垂直な方向に移動自在に支持している。音響管 11 の長さ L は、音響管 11 内の音圧が廻り込みの影響を受けないように 40 mm に設定されている。また、音響管 11 の開口 11 a からマイクロホン 13 までの距離 L_n は、振動壁 1（分割面 1 a）からの放射音が確実に平面波となるように 30 mm に設定されている。

【0043】振動壁 1 からの放射音の計測は、トラバース装置によって第 1 の音響管 11 を各分割面 1 a に対して移動させ、パワーアンプ 39 からスピーカ 33 への入力電圧 E を基準に音響管 11 内の音圧 P_i をマイクロホン 13 で計測することにより行った。この際、各分割面 1 a に対する音響管 11 の位置は、音響管 11 が各分割面 1 a の法線方向に沿って配置され且つ音響管 11 の一端の開口 11 a が各分割面 1 a から所定距離 h だけ離間するように調整した。この距離 h に関しては、1 mm, 5 mm, 15 mm の 3 条件について計測した。

【0044】同時に、本実験により得られた結果との比較のため、各分割面 1 a に図示外の反射テープを貼付し、非接触型のレーザ振動計（LDV）37 を用いて各分割面 1 a 毎に光軸の調整を行いながら振動速度の計測を行った。LDV 37 を用いたのは、加速度計による質量の影響を排除するためである。

【0045】図 5 (b) に示すように、実験に使用された第 2 の音圧測定装置 5 では、支持板 21 が、十分な剛性を有する厚さ 30 mm の鉄材で形成されている。マイクロホン 23 は、その集音部が第 2 の音響管 15 の一端の開口 15 a と相対向する支持板 21 の外面上に位置するように、支持板 21 に埋め込まれている。第 2 の音響管 15 は第 1 の音響管 11 とほぼ等しい大きさ及び形状を有し、支持板 21 に対しその法線方向に沿うように配置されている。第 2 の音響管 15 内のスピーカ 19 の図示外の振動板の面積は、予め所定面積 S_0 に設定されている。

【0046】スピーカ 19 からの放射音の計測は、スピーカ 19 からの放射音の音圧 P_0 をパワーアンプ 43 からスピーカ 19 への入力電圧 e を基準にマイクロホン 23 で計測することにより行った。マイクロホン 23 と音響管 15 の開口 15 a との前記法線方向に沿った距離 h に関しては、1 mm, 5 mm, 15 mm の 3 条件について計測した。

【0047】同時に、スピーカ 19 内の図示外の振動板

の振動速度 V_0 を図示外の $L D V$ によって計測した。 $L D V$ を用いたのは、振動板の質量が非常に小さく、接触型ではその重さによる影響を受けて分割振動やローリングが発生し易いためである。

【0048】マイクロホン 23 により計測されたスピーカ 19 からの放射音の音圧 P_i は、演算部 7 として的高速演算装置 (FFT) 41 へ入力される。FFT 41 には、振動板 17 の面積 S_i 及び $L D V$ により計測された振動速度 V_i が予め入力され記憶されており、 P_i 、 S_i 、 V_i から前記式 (4) に従って各距離 h 毎に伝搬特性 H_{pi} が算出され、出力される。

【0049】第 1 の音圧測定装置 3 のマイクロホン 13 により計測された分割面 1 a からの放射音の音圧 P_0 は、演算部 9 として的高速演算装置 (FFT) 35 へ入力される。FFT 35 には、FFT 41 によって算出された伝搬特性 H_{pi} 及び分割面 1 a の面積 S_0 が予め入力され記憶されており、これら P_0 、 H_{pi} 、 S_0 から前記式 (5) 及び／又は (6) に従って体積速度 Q_0 が分割面 1 a 毎に算出され、最終的にその加算値 ΣQ_0 が出力される。また、 $L D V$ 37 により計測された振動速度も FFT 35 へ入力される。FFT 35 では、 $L D V$ 37 により計測された振動速度に分割面 1 a の面積 S_0 を乗じることにより本実験における体積速度の理論値が分割面 1 a 毎に算出され、最終的にその加算値 ΣQ_t が出力される。

【0050】次に、本実験の結果について、図 6～図 9 に基づき説明する。

【0051】図 6 には、FFT 41 から出力された各距離 h 毎の伝搬特性 H_p が表されている。図 6 に示されるように、距離 h によるレベル差はあるものの、周波数特性は同一傾向を示し、距離 h が増えたとレベルも増加することが確認された。

【0052】図 7～図 9 には、相反定理に基づいた上記関係式 (5) を用いて、分割面 1 a 毎に算出した体積速度特性の加算値 (実験値) ΣQ_0 と、同様に $L D V$ 37 で直接的に計測した振動速度から分割面 1 a 毎に求めた体積速度特性の加算値 (理論値) ΣQ_n とが、音源である矩形の振動壁 1 と音響管 11 との間の各距離 ($h = 1 \text{ mm}$, 5 mm , 15 mm) 毎に表されている。なお、図 7～図 9 において、実験値 ΣQ_0 は破線で、理論値 ΣQ_n は実線でそれぞれ表示されている。

【0053】また、本実験において、実験値 ΣQ_0 を求めるための計測時間は、 $L D V$ 37 を用いた計測時間 (理論値 ΣQ_n を求めるための計測時間) に比べて、1/5 程度に短縮可能であることが確認された。

【0054】図 7 に示すように、距離 $h = 1 \text{ mm}$ の場合は、1 KHz まで各ピーク及びレベルが良好に一致し、その差がほぼ $\pm 3 \text{ dB}$ 以内であることが確認された。

【0055】図 8 に示すように、距離 $h = 5 \text{ mm}$ の場合は、300 Hz 以下で 4～5 dB の差があるが、その他

の領域では 1 KHz までその差がほぼ $\pm 3 \text{ dB}$ 以内であることが確認された。

【0056】図 9 に示すように、距離 $h = 15 \text{ mm}$ の場合は、1 KHz までのピークはほぼ一致するが、レベルは全体的に $+5 \sim +10 \text{ dB}$ の差を生じ、特に 500 Hz 以下での差が大きいことが確認された。

【0057】以上の実験結果により、相反定理により音響管 15 とマイクロホン 23 を用いた簡便な方法により、振動壁 1 から音響管 15 を含めた伝搬特性 H_{pi} を精度良く求めることができることが確認された。

【0058】また、求めた伝搬特性 H_{pi} と音響管 11 で計測した音圧 P_0 とを用いることにより、振動構造物の体積速度特性を精度良く簡便に求めることができることが確認された。

【0059】

【発明の効果】以上説明したように、本発明に係る計測方法及び計測システムによれば、被測定面に対して非接触状態で被測定面の体積速度 Q_0 が求められる。また、構造上大きな装置を含まないため大掛かりな設備を必要とせず、被測定面以外からの放射音は第 1 の音響管の外壁で反射されるので被測定面近傍の音源の影響を排除することができ、さらに、被測定面の反射率の変化や形状の影響を受け難く調整時間が不要であるため短時間で測定することができる。

【図面の簡単な説明】

【図 1】図 1 (a) は本実施形態の第 1 の音圧測定装置の模式図、図 1 (b) は本実施形態の第 2 の音圧測定装置の模式図である。

【図 2】図 2 (a) は第 1 の音響管がない状態を示す模式図、図 2 (b) は第 1 の音響管がある状態を示す模式図である。

【図 3】図 3 (a) は円筒状の音響管の内周面に消音材を貼着した状態を示す断面図、図 3 (b) は矩形筒体状の音響管の内面に消音材を貼着した状態を示す断面図である。

【図 4】他端が消音材で閉塞された音響管を示す断面図である。

【図 5】図 5 (a) は図 1 (a) に対応する実験装置の模式図、図 5 (b) は図 1 (b) に対応する実験装置の模式図である。

【図 6】本実施形態に係る実験により求められた各距離 h 毎の伝搬特性を表わす図である。

【図 7】距離 $h = 1 \text{ mm}$ の場合における体積速度特性の加算値の実験値と理論値とを表す図である。

【図 8】距離 $h = 5 \text{ mm}$ の場合における体積速度特性の加算値の実験値と理論値とを表す図である。

【図 9】距離 $h = 15 \text{ mm}$ の場合における体積速度特性の加算値の実験値と理論値とを表す図である。

【符号の説明】

1 振動壁

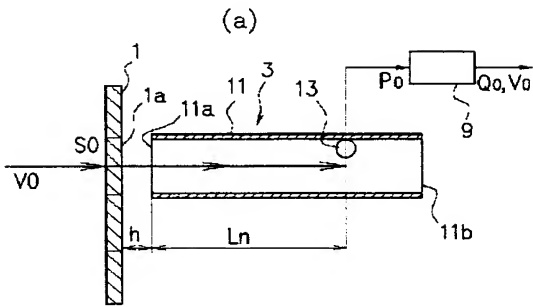
11

12

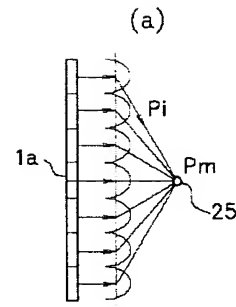
- 1 a 振動壁の分割面（被測定面）
 3 第1の音圧測定装置
 5 第2の音圧測定装置
 7 演算部
 9 演算部
 11 第1の音響管

- 13 マイクロホン（第1の音圧測定部）
 15 第2の音響管
 17 振動板
 19 スピーカ
 23 マイクロホン（第2の音圧測定部）

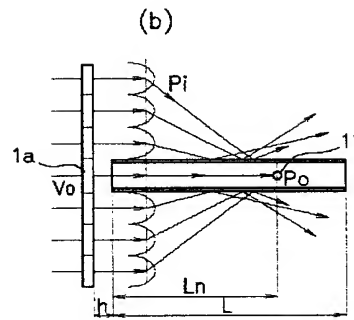
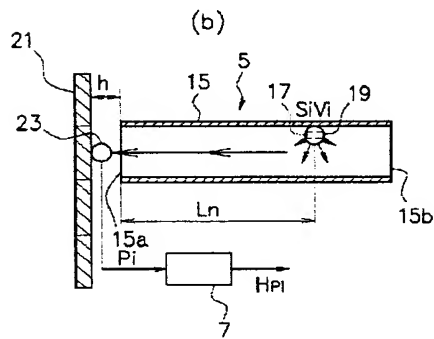
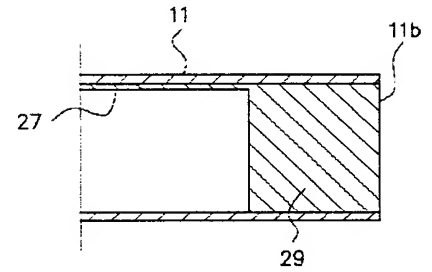
【図1】



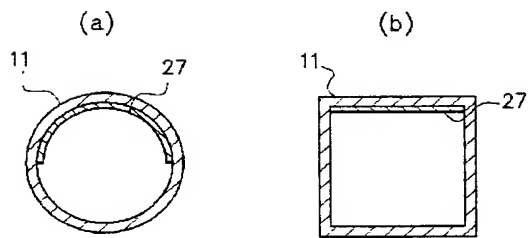
【図2】



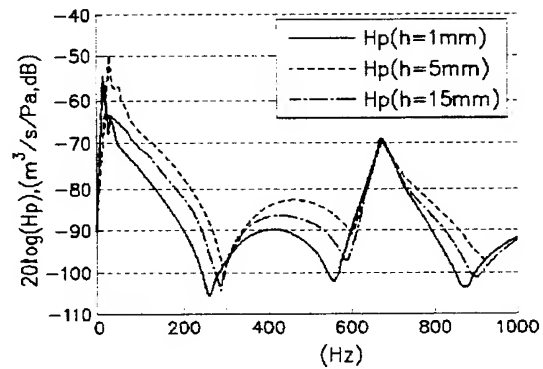
【図4】



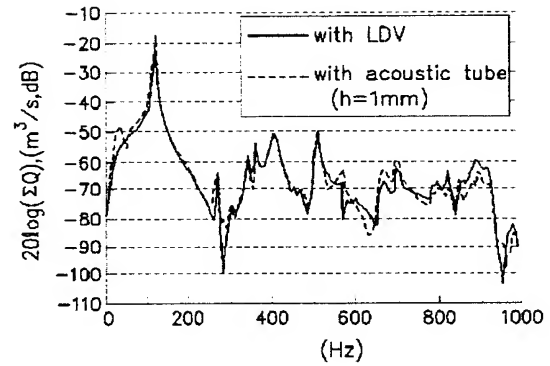
【図3】



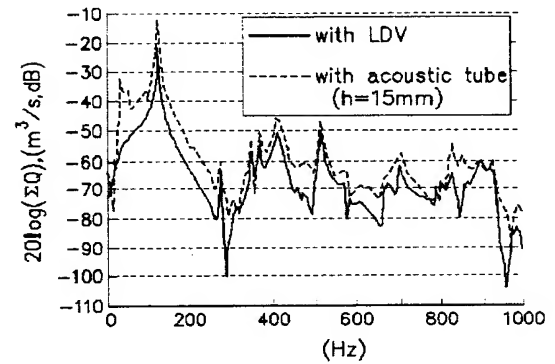
【図6】



【圖 7】



(b)



【補正方法】 変更

【補正内容】

【発明の名称】 振動計測方法及び振動計測システム

【補正対象項目名】発明の名称